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Ponderosa and Lodgepole Pine Seedling Bud Burst Varies With Lift Date and Cultural Practices in Idaho Nursery

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ABSTRACT

Bud break tests were conducted at Lucky Peak Nursery following six different lift dates from September to April. On the average, lodgepole pine seedlings consistently broke bud before ponderosa pine seedlings. For both species, bud break began sooner, accelerated faster, and was more complete with each successive lift. Fertilizer treatments did not affect time to bud break. Seedling moisture regime and soil texture, however, affected bud break differently for the two species. Daily temperatures and bud burst data were used to determine optimum lifting times.

KEYWORDS: nursery operation, dormancy, fertilizer, irrigation, temperature, ponderosa pine, lodgepole pine

Conifers of temperate climates are exposed to cool temperatures in the fall, which causes them to undergo physiological changes. These internal changes allow the trees to withstand the low temperatures of winter and to break dormancy and resume growth when environmental conditions become more favorable. The chilling requirements of several conifers have been studied: *Abies procera* Rehd. (Tung and others 1986); *Picea abies* (L.) Karst. (Dormling and others 1968; Worrall and Mergen 1967); *Pinus contorta* Dougl. (Ritchie and others 1985); *Pinus monticola* (Dougl. ex D. Don.) (Steinhoff and Hoff 1972); *Pseudotsuga menziesii* (Mirb.) Franco (Campbell and Sugano 1975; Lavender 1981; Lavender and Hermann 1970; Lavender and Stafford 1985; Lavender and Waring 1972; Nyland 1974; Ritchie 1984; Tung and others 1986); *Tsuga heterophylla* (Raf.) Sarg. (Nelson and Lavender 1979); and *Pinus ponderosa* Dougl. ex Laws. (Stone and Schubert 1959a).

Several investigators have found that bud-break speed may be an indicator of seedling vigor (Campbell 1978; Carlson 1985; Lavender 1985; Ritchie 1984; Ritchie and others 1985) and that dormancy is composed of three main parts. The first and third are periods of quiescence when seedlings can be induced to grow in a favorable environment. Kramer and Kozlowski (1979) also refer to these reversible periods of inactivity (quiescence) as predormancy and postdormancy. In between is a rest period when seedlings are dormant because their chemical balances prevent them from growing (Lavender and Stafford 1985). Lavender (1991) recognized four stages of dormancy when he divided the rest period into two stages: correlated inhibition and rest. Initiation and cessation of dormancy may be triggered by a number of variables including photoperiod, light quality, temperature, nutrition, water, various chemicals (hormones), and shock treatments (Hinesley 1982; Kramer and Kozlowski 1979; Perry 1971). The environmental factors that can induce dormancy vary between species. In temperate trees, dormancy can be brought on by shortened day length and/or cold temperatures.

In nature the early stages of dormancy are still reversible, and shoot elongation can be made to resume. But as the process progresses it eventually becomes irreversible. At this point a tree has entered a resting stage and must go through a chilling period before normal growth will again take place (Glerum 1982). The chilling requirement is the number of accumulated hours at cold temperatures that are needed before a tree can resume growth. When the chilling requirements have been

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Table 1—Comparison of eight fertilizer treatments in pounds/acre (kg/ha) and a control. An "x" for each treatment indicates the type of fertilizer and application rate

Treatment	Incorporated					Top dressing (ammonium nitrate)	
	Milorganite		Ammonium nitrate		Treble superphosphate		
	1,000 lb (1,120 kg)	*2,000 lb (2,240 kg)*	*88 lb (99 kg)*	*176 lb (197 kg)*	*68 lb (67 kg)*	*88 lb (99 kg)*	*176 lb (197 kg)*
F1	x	—	—	—	—	x	—
F2	—	x	—	—	—	—	x
F3	—	—	x	—	—	x	—
F4	—	—	—	x	—	—	x
F5	x	—	—	—	x	x	—
F6	—	x	—	—	x	—	x
F7	—	—	x	—	x	x	—
F8	—	—	—	x	x	—	x
Control	—	—	—	—	—	—	—

satisfied but shoot elongation does not occur because environmental conditions are not favorable for growth, then the tree is held in a state of imposed dormancy or postdormancy.

Burdett and Simpson (1984) suggest that rather than describing the whole plant, the term dormancy should be used to describe the individual localized activity of each of the three meristematic zones: the shoot apex, the root apex, and the vascular cambium. Growth potential, the actual growth under optimum environmental conditions, is often not correlated in these tissues. The test for bud dormancy is to put the plant in an environment conducive to growth. The test for root dormancy is the root-growth capacity measurement (Stone and Schubert 1959b). Dormancy in the vascular cambium may seldom exist (Lavender and others 1970; Little and Bonga 1973; Worrall 1971).

This report will present the results of bud burst trials on lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) after several different lift dates from early fall to spring at Lucky Peak Nursery, Boise, ID. We also investigated how the speed of bud burst was affected by fertilizer, water treatments, and soil texture during the growing season.

METHODS

The seedlings used in this study were 2-0 bareroot ponderosa pine (Cascade District, Boise National Forest, elevation 5,400 feet) and lodgepole pine (Ashton District, Targhee National Forest, elevation 6,500 feet). They were grown at Lucky Peak Nursery on two soils with different textures: a sandy loam and a clay loam that displayed the physical properties of a much heavier soil. Three moisture regimes were imposed in a random fashion on both soil types during the second growing season. The moisture regimes consisted of: (1) moist (early morning plant moisture stress levels held below –0.5 MPa (Mega Pascals) for the entire irrigation season); (2) medium (early morning plant moisture stress levels held below –1.0 MPa between July 15 and September 1, and held below –0.5 MPa before July 15 and from September 1 until the end of the irrigation season); and (3) dry (early morning plant moisture stress levels held below –1.5 MPa between July 15 and September 1, and below –0.5 MPa before July 15, and from September 1 until the end of the irrigation season). Plant moisture stress measurements were all taken before dawn with a pressure bomb apparatus.

Within each moisture regime, eight fertilizer treatments and one control plot were established. This made a total of 54 treatments per species each lift date. The fertilizer treatments consisted of various combinations of presown milorganite, ammonium nitrate, and treble super phosphate plus later top dressings of ammonium nitrate. Table 1 presents the fertilizers and how they were applied for all of the treatments.

Seedling lifting began September 18, 1984. The second lift followed 4 weeks later and subsequent lifts were at 3-week intervals, ending April 8, 1985. Frozen ground at the nursery prevented lifting during the winter months. Immediately following each lift, five trees from each sample plot were potted in 7-inch pots. The potting medium consisted of a 1:1:1 mix of peat, vermiculite, and sandy loam soil.

Potted seedlings were placed in a greenhouse at temperatures held between 60 and 80 °F and photoperiods of 16-hour light, 8-hour dark. Bud burst was recorded for each tree at the first sign of green needles protruding from sheaths on the terminal bud.

RESULTS AND DISCUSSION

Unfortunately, a reliable statistical analysis could not be performed because of the split plot design and several holes in the data set. These problems even precluded analysis of data subsets. Nevertheless, several interesting relationships were observed.

Lodgepole pine seedlings consistently broke bud before ponderosa pine and on the average were almost 2 weeks earlier for the last three lifts (November 26, March 18, and April 8) (tables 2 and 3). When percentage of bud burst is graphed over days since potting, the resulting curves have the characteristic sigmoid shape shown by Nyland (1974) (figs. 1,2,3). With each successive lift, bud-burst curve begins sooner, is steeper, and the percentage of bud burst is more complete.

Nursery bed fertilizer treatments had no apparent effect on time to bud burst for either species.

Lodgepole Pine

When lifted in mid-September, only 2 percent of the lodgepole seedlings broke bud after 120 days in the greenhouse. From that point, bud burst progressed slowly, yet after 150 days only 29 percent of the trees burst bud. By the mid-October lift, the seedlings had received some chilling, but still only 50 percent broke bud in the greenhouse after 120 days. Eighty-three percent of the trees broke dormancy in the 120-day greenhouse period when lifted in early November. Most of the bud break occurred within 75 days (fig. 1).

When the lodgepole seedlings remained in the nursery beds until late November, essentially 100 percent broke bud in the greenhouse. Not only was the bud burst more complete with each successive lift, it also began earlier and was more rapid each time. All three of these bud-burst characteristics, namely consistency, timing, and speed, are keys to the stage of dormancy. Data from the first four lifts show that the lodgepole pine seedlings were probably ready to be lifted about mid-November when based solely on the condition of the buds. In order to be certain of dormancy elsewhere in the seedlings, root growth potential or cold hardiness should also be tested. Although a strong relationship exists among bud dormancy, cold hardiness, and root growth potential, Burr and others (1989) found cold hardiness to be the most accurate indicator of overall dormancy.

Table 2—Mean number of days to bud burst for lodgepole pine seedlings grown under three moisture regimes and on two soils with different texture and lifted on six different dates. Seedlings lifted September 18 that did not break bud in 160 days were given values of 160 days. Seedlings lifted on the other lift dates and that did not break bud during the test were given values of 125 days

		Lift dates					
Soil type	Moisture	Sept. 18	Oct. 15	Nov. 5	Nov. 26	Mar. 18	Apr. 8
Sandy loam	Moist	150.6	114.4	70.5	35.3	9.9	5.5
	Medium	150.9	111.9	65.6	37.7	7.7	2.8
	Dry	142.6	106.7	59.6	37.0	9.6	3.2
Average		148.0	111.0	65.2	36.7	9.1	3.8
Clay loam	Moist	152.4	111.0	67.1	40.2	11.8	6.6
	Medium	154.2	106.4	56.1	37.7	11.4	4.9
	Dry	140.4	108.5	67.1	44.1	11.6	3.5
Average		149.0	108.6	63.4	40.7	11.6	5.0
Both soils	Moist	151.5	112.7	68.8	37.7	10.9	6.1
	Medium	152.6	109.2	60.9	37.7	9.6	3.9
	Dry	141.5	107.6	63.4	40.6	10.6	3.4
Total average		148.5	109.8	64.3	38.7	10.3	4.4

Table 3—Mean number of days to bud burst for ponderosa pine seedlings grown under three moisture regimes and on two soils with different texture and lifted on six different dates. Seedlings lifted September 18 that did not break bud in 160 days were given values of 160 days. Seedlings lifted on the other lift dates that did not break bud during the test were given values of 125 days

		Lift dates					
Soil type	**Moisture**	**Sept. 18**	**Oct. 15**	**Nov. 5**	**Nov. 26**	**Mar. 18**	**Apr. 8**
Sandy loam	Moist	159.9	121.7	111.2	50.5	23.1	14.6
	Medium	146.3	109.3	97.1	46.2	20.3	14.2
	Dry	157.3	122.6	113.0	60.8	24.9	11.5
Average		154.5	117.9	107.1	52.5	22.7	13.4
Clay loam	Moist	160.0	121.0	116.5	55.2	26.6	20.4
	Medium	159.8	122.1	111.7	61.2	25.6	19.3
	Dry	160.0	118.3	117.8	57.6	23.5	15.1
Average		159.9	120.5	115.3	58.0	25.2	18.3
Both soils	Moist	160.0	121.4	113.9	52.5	24.9	17.5
	Medium	153.1	115.7	104.4	53.7	23.0	16.8
	Dry	158.7	120.5	115.4	59.2	24.2	15.5
Total average		157.2	119.2	111.2	55.3	24.0	15.5

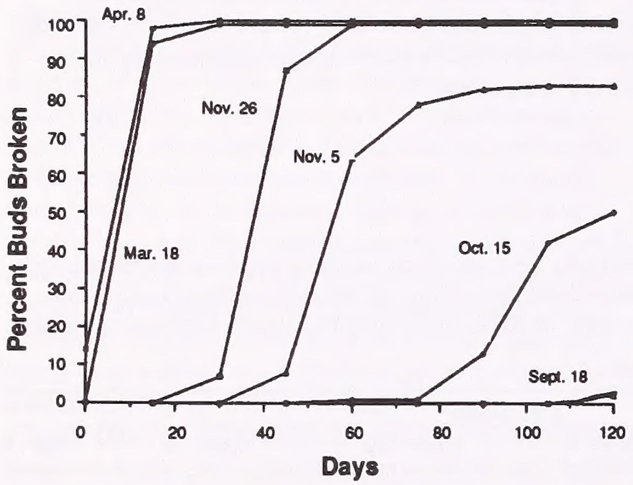

Figure 1—Lodgepole pine seedling bud burst rates after six different lifting dates from September 1984 to April 1985. Each curve represents the percentage of seedlings to break bud out of 270 for each lift date. Seedlings total 1,620.

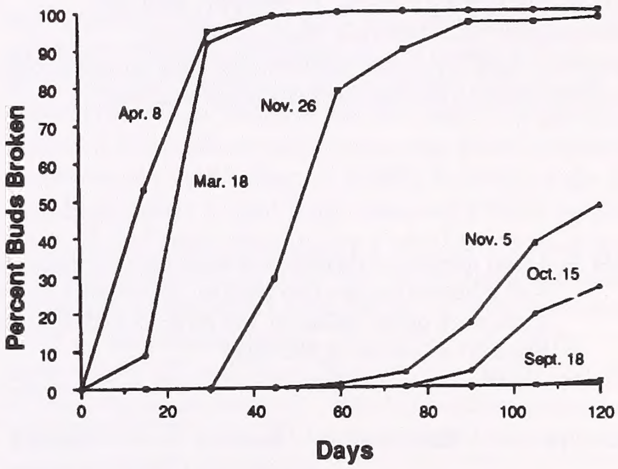

Figure 2—Ponderosa pine seedling bud burst rates after six different lifting dates from September 1984 to April 1985. Each curve represents the percentage of seedlings to break bud out of 210 for each lift date. Seedlings total 1,260.

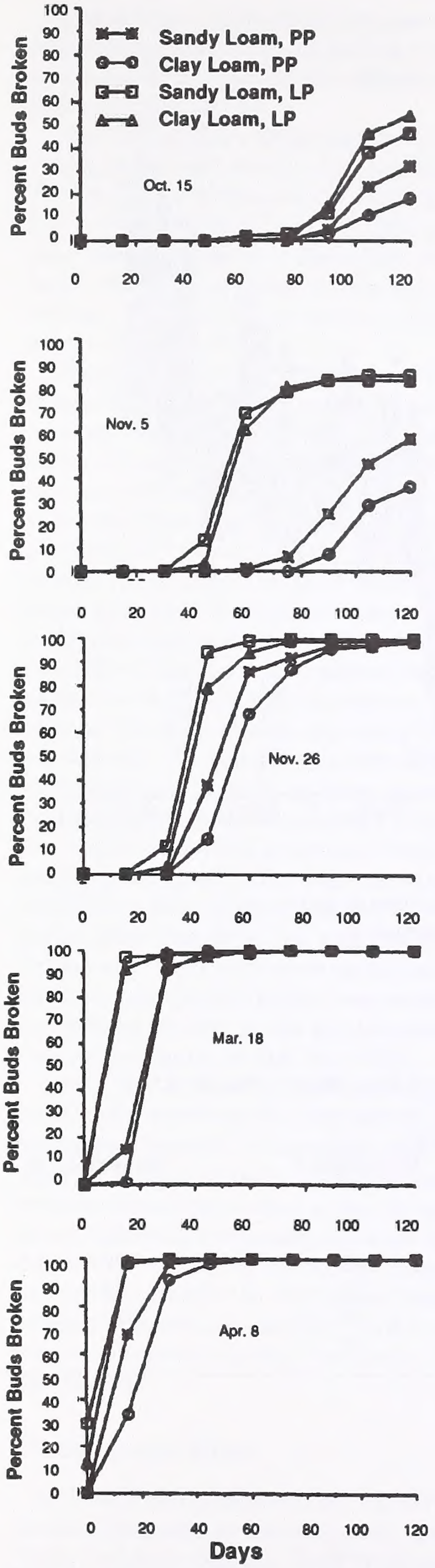

Figure 3—Comparison of bud burst rates for lodgepole and ponderosa pine from sandy loam and clay loam soils. Seedlings were lifted at Lucky Peak Nursery from October 1984 until April 1985.

Because we do not know the critical temperature or temperatures required to satisfy seedling-chilling requirements, it is not possible to pinpoint when the lodgepole-chilling requirements were met. The data show that the seedlings were ready to grow sometime between the third and fourth lift dates. Therefore, we can see in figure 4 the accumulation of minimum temperatures that led to bud burst in the fall of 1984 at Lucky Peak Nursery. Table 4 presents a summary of the same temperatures in a cumulative fashion, with low temperatures below 40, 36, 32, and 28 °F (4.4, 2.2, 0.0, and –2.2 °C), respectively, at the time of the four fall lifting days. It appears that in this case, lodgepole pine seedlings needed approximately 50 days with low temperatures below 40 degrees, 35 days below 36 degrees, or 30 days below 32 degrees for all of the seedlings to break bud. This is undoubtedly an oversimplification of the dynamics taking place within the seedlings. According to Lavender (1991) most models that attempt to predict satisfactory chilling requirements use temperatures in the range of 40 to 45 °F (4 to 7 °C). Burdett and Simpson (1984) found that root growth capacity was most closely related to cumulative hours below 41 °F (5 °C), but little information exists concerning the relationship between temperature and lodgepole pine bud dormancy. Several years of measurements on the same seedlot will be required to pinpoint the best critical temperature, if there is one, and the number of chilling days needed by lodgepole pine before the seedlings are able to consistently break bud.

Springtime warming allows for trees to break dormancy and begin growth. Figure 4 also shows the cumulative high temperatures before the two spring lifts. This summary of temperatures does not tell us what the requirements are for bud burst. It does show us the temperatures that have made the lodgepole pine seedling tops ready to grow immediately upon exposure to favorable conditions, on March 18. By April 8 they were beginning to grow in the nursery bed.

We did not lift any trees between November 26 and March 18 because of frozen soil. When the frost finally left the ground in mid-March, the lodgepole seedlings broke bud very quickly in the greenhouse. Within 15 days nearly 100 percent of the trees broke bud, while in late November it took 45 days to achieve the same amount of bud burst.

Three weeks later the seedlings were so close to breaking bud in the nursery bed that 14 percent did break bud in the time period between lifting and when they were placed in the greenhouse. This indicates that the lodgepole seedlings were coming out of dormancy before the spring lifts.

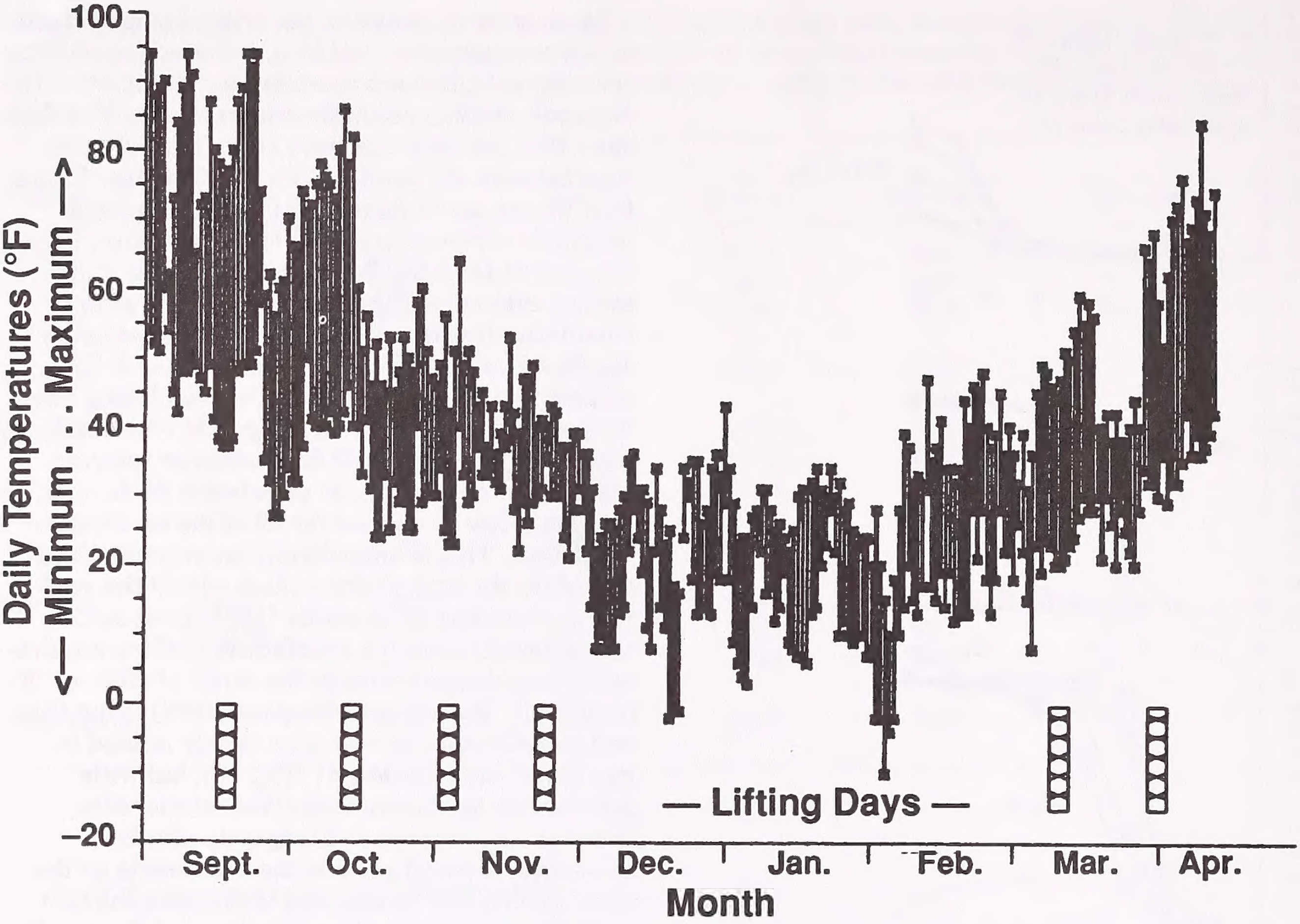

Figure 4—Minimum and maximum daily temperatures at Lucky Peak Nursery for fall 1984 to spring 1985. Bars depict the timing of the six lifting dates: September 18, October 15, November 5, November 26, March 18, and April 8.

Table 4—Number of days temperatures fell below four reference temperatures prior to lifting dates in the fall of 1984

Reference temperatures		Lifting dates			
		September 15	October 15	November 5	November 25
°F	*°C*				
40	4.4	[1]4	22	42	62
36	2.2	0	10	28	45
32	0	0	7	23	36
28	–2.2	0	2	10	15

[1] Prior to September 15 (first lift), daily low temperatures dropped below 40 °F four times.

There is very little difference between bud burst of seedlings grown on the heavier nursery soil compared to those from the lighter soil, especially in the later lifts (fig. 2).

The effects of the three moisture regimes on bud break are so variable that interpretation is difficult. The lack of statistical analysis further complicates the problem (table 2). In the first two lifts on the clay loam soil and first three lifts on the sandy loam, the high moisture treatment seems to be behind the driest treatment in average number of days to bud break.

This may be because the drier conditions late in the summer caused the trees in the medium and dry regimes to cease growth and start to go dormant earlier than the moist treatment. Many investigators have found that dormancy in seedlings can be enhanced through the use of irrigation. In fact the physiological changes that take place during repeated periods of mild water deficit seem to parallel those that come during cold hardening (Johnson 1986; Johnson and others 1985; McDonald 1984; McNabb 1985; Zaerr and others 1981). One explanation for this is that the solute potential is decreased during moisture stressing through osmotic adjustment. In this process solutes are accumulated in the cells, making them more frost resistant and giving them the capability to take up water at low water potentials (Johnson 1986). Therefore, seedlings exposed to the high moisture treatment could have been slightly behind in the fall dormancy cycle. After the third lift, average days to bud burst values are closer and more variable. This indicates that the trees in the moist treatment have caught up and are similar to the dry treatment in overall level of dormancy in the later lifts.

Hsiad (1973) reported that carbohydrates tend to build up in seedlings during periods of mild moisture stress because of a greater effect on growth than on photosynthesis. A higher concentration of carbohydrates may allow a tree to begin growing faster following dormancy, because it will not depend as heavily on current photosynthesis for its energy for growth. In this study, there was not enough difference in seedling bud break between moisture regimes during the spring lifts to support this theory.

Ponderosa Pine

Although the ponderosa pine seedlings were treated the same as the lodgepole, they consistently broke bud later (fig. 3). Very little bud break took place after lifting in mid-September: budbreak was only 1 percent with 120 days in the greenhouse and 14 percent after 150 days (fig. 2). Bud burst progressed very slowly following the early November lift but took a big jump in the late November lift. This shows that the ponderosa pine seedlings received sufficient chilling by late November to break dormancy on a large scale. Until that time, most of the seedlings were not ready. For comparison, the minimum daily temperatures are presented with lifting dates in figure 4. It may take about 60 days with minimum temperatures below 40 °F (4.4 °C) or 45 days with temperatures dipping below 36 °F (2.2 °C) (table 3). Burr and others (1989) found that once dormancy in ponderosa pine is achieved, no further chilling is required to break dormancy and initiate growth.

In mid-March the bud break came much sooner and more rapidly than any of the previous lifts. Close to 90 percent of the seedlings burst bud within the period of 15 to 30 days after potting. For the early April lift the bud burst began a little sooner, but the curve was not as steep as in mid-March.

Unlike the lodgepole seedlings, the ponderosa trees from the sandy loam were generally ahead of trees from the clay loam soil in their bud burst (fig. 3). Seedlings grown on the clay loam soil averaged from 2.5 to 5.5 days behind those from sandy loam soil in bud break speed (table 2). Because the heavier soil held more moisture, it tended to cool off later in the fall and warm up later in the spring. This could explain the lag.

When comparing the differences in seedling bud burst from the three moisture regimes, there seem to be no trends (table 2). On the average, seedlings in the dry regime were quicker to break bud several times, the moist regime was quicker once, and the medium regime was first most often. All three moisture regimes also showed the longest average days to bud burst at one time or another.

CONCLUSIONS

With each successive lift, bud burst began sooner, accelerated faster, and was more complete. On the average, lodgepole pine seedlings burst bud sooner than ponderosa pine after each of the six lift dates. Ponderosa pine seedlings grown on a sandy loam soil generally broke bud before those grown on a clay loam, but soil had no effect on lodgepole pine seedlings. Fertilizer treatments did not have an effect on dormancy for either species. The drier water regimes tended to cause bud break sooner than the moist regime for lodgepole pine in the early lifts, but the results were not conclusive.

These bud break tests indicate that the lodgepole pine seedlings fulfilled bud chilling requirements by early to mid-November. Ponderosa pine buds were ready to grow by late November. Normally, additional chilling beyond that required for bud burst reduces the variability of the average number of days to bud break between seedlings. This is also apparent in the data presented. More consistency between seedlings is generally considered to be advantageous, because fewer resources are required for quality testing and more consistent field results can be expected.

In mid-March the ponderosa pine had not yet broken bud. Ideally, the lodgepole pine should have been lifted before mid-March to ensure maximum vigor. When the lodgepole seedlings were lifted in mid-March, bud burst was almost immediate.

More research is needed with these and other seed sources in order to get a better concept of their chilling requirements. It would also be helpful in future studies to attempt to relate bud burst to root growth potential and cold hardiness for a better overall picture of seedling dormancy.

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INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

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